roll. This form of packaging did not become an accepted sales instrument at that time, but was revived later.

Seed packages must be labeled to show the species, variety, percentage of live seed, purity, content of noxious weeds, and seed treatment, if any. The information may be printed on a tag attached to the bag. It may be printed on a label that is glued to the container. It may be printed or stamped directly on the container. Seedsmen usually print their own tags and labels.

Stenciling on bags may be done manually or automatically by rotary printer as the container passes a point on an assembly line. Embossing normally is done by the closing machine.

Special labeling machines can apply glue to the can or label and wrap the label around the can as it rolls through the machine. A special printer may imprint information on the can before the label is applied so that it can be identified even if the label is removed.

The final packaging operation is the assembling of the packages. Large containers may be brought together by belt or roller conveyor or placed by hand on pallets handled by forklift, or by use of handtrucks. Smaller units frequently are placed in larger cartons by hand or automatically with equipment built to assemble a selected number of units and place them in cartons.

The seeds are then ready for transportation and distribution to their eventual destination—in the good earth, where their germination will demonstrate the protective value of modern packaging.

LOUIS N. BASS *is a plant physiologist in the Agricultural Research Service, National Seed Storage Laboratory, Fort Collins, Colo. Formerly he was assistant professor of botany and plant pathology in Iowa State University.*

TE MAY CHING *is an assistant agronomist, Farm Crops Department, Oregon Agricultural Experiment Station, Corvallis.*

FLOYD L. WINTER *is vice president and director of breeding and research, Asgrow Seed Co., New Haven, Conn.*

Transporting, Handling, and Storing Seeds

LEO E. HOLMAN AND JAMES R. SNITZLER

FARMERS plant alfalfa seed from California, ryegrass seed from Oregon, whiteclover seed from Idaho, redtop seed from Illinois or Missouri, sudangrass seed from Texas, tall fescue seed from Kentucky, and orchardgrass seed from Virginia.

The seed is transported from the place of production to the place of planting by railroads, trucks, and ships. The primary users of these facilities are middlemen, who assemble, process (the seed industry calls it conditioning), store, and ship the seed to large-scale growers or to other middlemen, who sell it to those who plant it.

More than 3 million tons of seeds were transported from producer to user in 1959. That tonnage would fill about 200 thousand tractor-trailers or 100 thousand rail cars.

That fact brings out an interesting point.

THE TONNAGE of seeds is substantial, but it is small compared to the total tonnage of agricultural products that the carriers haul. It was only 2.6 percent of the tonnage of agricultural products hauled by the railroads and about 1 percent of the combined tonnage of agricultural products hauled by the three major types of carriers.

The small percentage that seed bears to total agricultural tonnage belies its importance to the carriers and to the Nation's economy. Our entire agricultural production depends on the delivery of seed to the right place, at the right time, and in the right condition. The tonnage of seeds thus is a generator for the total tonnage of our agricultural products.

Domestic-grown seed sold off farms was 94 percent of the total seed hauled in this country in 1959. The rest was imported.

Wheat, corn, rye, oats, rice, sorghums, barley, and buckwheat made up 41 percent of the total tonnage.

Vegetable seeds and potatoes were next in importance—29 percent. Field seeds (principally grasses and legumes) and oilseeds (soybeans, peanuts, and flax) each accounted for about 14 percent. A miscellaneous group consisting of seeds of cotton, tobacco, flowers (imported), trees, and shrubs made up the remaining 2 percent.

ALL MODES of transport are used in hauling seeds. The railroads, the predominant carriers, hauled 1.8 million tons, or 60 percent of the total. These rail and truck percentages represent primarily the long-haul movement of seeds—that is, from the country assembly points through the various wholesale trade channels to the retail stores. The short-haul movement, from the farm to the country assembly point and from the retail outlet to the farm, is nearly all by truck.

The long-haul movement of seeds also involved the use of boats and airplanes, but the combined tonnage hauled by them probably did not exceed 3 percent in 1959.

Most of the tonnage carried in barges and lake and coastwise freighters consisted of grass and legume seeds grown in Oregon and shipped through the port of Portland to destinations on the gulf and Atlantic coasts.

Seed shipped by air is primarily experimental and high-value seed for which the buyer is willing to pay the higher cost of this premium service.

Parcel post is used extensively for small shipments of vegetable and flower seeds, but it utilizes one or more of the types of carriers previously mentioned—mainly rail and truck.

Privately owned and for-hire trucks are used to transport seeds.

Private trucks do most of the short-haul shipments. They are owned or leased by producers and wholesale buyers, who haul the seeds from the farm to the country assembly point for reshipment; farmers, who purchase the seed from the local retail seed dealers and haul it to their farms; and retail dealers, who provide delivery service to the farm.

The truck share of the long-haul movement (from the country assembly point to the retail outlet) is hauled largely by for-hire motor carriers. These are truck operators whose primary business is to haul commodities or other types of merchandise for the general public for compensation.

Two types of for-hire motor carriers engage in hauling seeds—exempt and regulated. This distinction is based upon the Motor Carrier Act of 1935, which provided generally for the Federal regulation of motor carriers engaged in interstate transportation.

The act contained exemptions for vehicles hauling nonmanufactured agricultural commodities, such as fresh fruit and vegetables, grain, poultry and eggs, ordinary livestock, and seeds.

The term "exempt carrier" is applied to motor carriers that haul exempt commodities only. They are subject to rules and regulations of the Interstate Commerce Commission as to safety and hours of service of drivers, but they are not subject to regulation by the Commission over entry into the trucking business, the rates charged, and routes served.

Regulated carriers hold authority from the ICC for the transportation of other than exempt commodities. They may also haul exempt commodities and, when doing so, are not subject to economic regulation by the ICC as to those commodities, as long as no nonexempt commodities are moved in the same truck at the same time.

Exempt agricultural commodities, such as seeds, serve to balance out the return-haul movement for many regulated motor carriers, particularly the large regulated motor carriers in the Far West, since their inbound tonnage of manufactured goods for California and the Pacific Northwest exceeds the outbound tonnage of this type of merchandise. Not all of the truck portion of the seed tonnage moving from the Far West is hauled by the regulated motor carriers, however. Exempt motor carriers also haul a part.

Both exempt and regulated motor carriers haul seed grain from the production branches or country warehouses of seed wholesalers in the Midwest to their retail dealers. Exempt truckers are also used extensively in hauling seed potatoes from Boston to growers and dealers in the Middle Atlantic and Southeastern States. This haul is particularly attractive to the exempt trucker, since ordinarily he has delivered a load of fresh fruit, vegetables, or citrus fruit to New England and is looking for a return haul to the Southeast.

AN ADVANTAGE of using rail carriers to ship seed is the transit arrangement. Seed may be shipped from California to a wholesaler in the Midwest, where it may undergo further processing and then be forwarded to the final destination at the rate that applied to a direct movement of seed from its origin to final destination.

An example, based on the rail rates in effect in February 1960, illustrates the cost advantage of this transit privilege to a Midwest wholesaler. The through rate for a shipment moving directly from California to final destination in Illinois is 1.35 dollars per hundredweight. Without the transit privilege, the wholesaler would pay the local rate of 1.29 dollars from the California production area to a transit point in Missouri. After the seed has been processed and prepared for reshipment, he would again pay a local rate—this time 99 cents from the transit point to Illinois. The combination of local rates would result in a total transportation cost of 2.98 dollars per hundredweight.

Under the transit arrangement, the wholesaler would pay only 1.405 dollars per 100 pounds. This includes the local rate of 1.29 dollars from the California production area to the Missouri transit point, a separate transit charge of 5.5 cents per 100 pounds, and a balance on the outbound shipment of 6 cents per 100 pounds (the difference between the local rate of 1.29 dollars and the through rate of 1.35 dollars).

The saving on the transit privilege is 87.5 cents per 100 pounds, or 700 dollars on a carload shipment of 80 thousand pounds.

The saving is a major reason why many shippers of seeds prefer rail transportation. Some shippers, however, have found that sometimes it is cheaper to use trucks for either the inbound or outbound movement, although by so doing they give up the transit privilege and thus must pay the local rail rate in combination with the truck rate. The railroads have lowered their rates in some instances to meet this truck competition.

Convenience of loading and unloading is another advantage of using rail transportation for shipping seeds. The shipper or receiver has 48 hours free of charge for loading or unloading the car after it has been placed at his disposal. Additional time beyond the 48 hours is subject to the payment of a published demurrage charge.

Trucking companies do not consider this type of service economically feasible, because the driver and perhaps an alternate driver will accompany the equipment and must be paid for waiting time. The truckers therefore are anxious to get their equipment loaded and unloaded as quickly as possible and back on the road.

Rail carriers can handle large shipments on long hauls at low rates. For example, some seeds, such as beans and peas, are shipped from the Far West with minimum carload quantities as high as 80 thousand pounds. The railroads introduced these high minimum carload weights to encourage the shippers to load the cars more heavily. For example, the rail rate on dry beans shipped from California to Texas is 1 dollar per 100 pounds for carloads with a minimum weight of 80 thousand pounds. The rate is 2.24 dollars a hundredweight for carload shipments with a minimum of 40 thousand pounds.

TRUCKS usually can make deliveries from the warehouse of a seed wholesaler to his customers in less time than it would take to move them by rail.

Speed is important late in the planting season, when retail dealers may run out of certain varieties of seeds and need refill orders immediately or when emergency conditions, such as floods and droughts, may have ruined a farmer's first planting and he needs seed for replanting.

Speed also is important in the servicing of the supermarket trade by seed wholesalers. Because the large chains operate on the basis of a fast turnover and a minimum of inventory, they need to replenish their stocks of seeds several times during the season. They therefore specify the date and hour of delivery, a date that makes mandatory the fastest transportation.

A large share of the seed-marketing business does not require fast delivery service, of course. Because most of the seed of grass, legumes, grains, vegetables, and flowers are harvested in the late summer and fall, several months elapse before it is needed for planting. During this interval, the seed is in storage in the wholesaler's warehouse. In order to reduce his storage risk and to insure a more orderly method of distribution, he begins shipments to independent retail seed dealers as early as December. He uses rail and truck transportation.

To induce the retailer to carry an inventory of seeds during the winter, the wholesaler may postpone payment of the invoice until April or May, grant quantity discounts, and allow the retailer to deduct a warehousing allowance from the invoice.

Motortrucks also provide pickup and delivery service. This service is particularly important for customers who are not on a railroad. Among them are farmer agents, who, as sales agents for the wholesalers, sell seed to other farmers in their locality.

Whether he uses railroad or truck transportation, the shipper ordinarily can partly load the car or truck at one place and complete the loading somewhere else. The car or truck may also be stopped for unloading at several places. This service is important, especially for rail shipments, because many retail dealers lack storage space for handling a full carload of seed.

The motor carriers generally make a separate charge ranging from 5 to 10 dollars a stop, and the railroads 15 to 20 dollars, depending on the area.

Stopping in transit to load or unload some of the seed allows the buyers to obtain the benefit of lower carload rates that are often available on heavier shipments.

BOTH SHIPPERS and carriers are responsible for taking protective measures to insure that seed arrives at its destination in satisfactory condition. The shipper's responsibility is to see that the seed is properly loaded and secure from the ordinary transportation hazards. The carrier's responsibility is to deliver the seed to the destination in the same condition that it was received at the shipping point.

A major type of loss and damage to seed shipments is from torn sacks or bags. It is associated largely with rail shipments. It causes loss of the seed containers and the seed itself. A common cause is protruding nails and bolts and loose or splintered boards. Any shifting of the load when one car bumps into another in switching operations or when a long freight train starts or stops can cause a bag of seed to be ripped open if it is lying against a rough or sharp object.

Water may cause shipping containers to split apart. It may damage the seed itself, for excess moisture and warm temperature can cause enough heat to generate in the seed to destroy its ability to germinate or to give it an odor strong enough to make it unsalable. Leaky roofs, loose-fitting doors, and worn tarpaulins may lead to such damage, which occurs more frequently in truck shipments than in rail.

Industrial chemicals and oil residues that were not removed from the rail car or truck before loading may cause the bags to disintegrate. The container may soak up some of the residues or take up an odor from them.

Freezing hurts some seeds, such as potatoes. To avoid that, portable heaters are placed in the truck or car for shipments in winter, but overheating is not good.

Grain that is moved in bulk into the wholesaler's plant for further processing may suffer damage and loss in transit because of loose doors, loose or broken floorboards, or cracks in the floor.

Protective measures include inspection of the carrier's equipment by the shipper to determine whether it is in fit condition for hauling seeds. Since the general rule is to keep seeds dry and cool, even a brief inspection of the inside and outside of a rail car or truck should reveal whether it is possible to maintain these conditions.

Such inspection should also reveal the presence of loose or broken wallboards or floorboards, protruding nails or bolts, broken pieces of wire strapping, chemical or oil residues or other material left in the car which might damage the seed or its containers.

If it appears that the equipment cannot be put in satisfactory condition, the shipper should ask the carrier to replace it with equipment that is fit for hauling seeds, since the responsibility for accepting or rejecting equipment for loading rests with the shipper.

Once the carrier has provided adequate equipment, the responsibility for preparing it for loading rests with the shipper only when shipping in rail carlots, because only then is the responsibility for loading his. For shipments by truck, the truck operators generally do their own loading and must see to it that their equipment is in proper condition. Not, however, that these protective measures are solely for the benefit of shippers: Truck operators also can benefit thereby through reductions in loss and damage claims.

An additional step in preparation for loading is to sweep out the car carefully. The floor, sidewalls, and ends of the car should then be lined with heavy kraft paper.

Special precautions need to be taken for bags or cartons stacked near the doorway of a rail car. That can be done by using strips made of heavy paper, reinforced at regular intervals with steel strapping and nailed to the doorposts through prepunched holes in the strappings. For bulk shipments, one-piece doors of wood or heavy-duty, water-repellent paperboard, reinforced with steel strapping, are placed inside the regular car doors.

Another protective measure for loads of bags of various weights is to place the heaviest bags on the bottom to prevent the bags splitting open from the overhead weight. The bags should be stacked tightly together in an interlocking pattern to lessen chances that the load may shift in transit.

Sometimes a properly loaded shipment may be damaged by the receiver when it is being unloaded. To prevent this loss, one shipper prints this note of caution on the loading chart and tally sheet, which is tacked to the wall inside the loaded car: "Do not drag bags over the car floor. Be careful in removing bottom and outside layer of bags. Care has been taken to remove all nails and bolts before loading, but some may work out in transit. A little care on your part will offset considerable damage to the goods."

Seeds should be handled more like eggs than like stones.

Much of the modern equipment for handling materials can be used safely for handling most kinds of seeds.

Bucket elevators or legs of the centrifugal-discharge type are used extensively to move seeds vertically in bulk. Buckets, mounted at spaced intervals on belts or chains, are loaded by scooping up seeds from the boot at the bottom. The seeds are discharged by centrifugal action as the belt passes over the head wheel. The speed of the belt must be held within close limits so the seeds will discharge properly—fast enough that the seeds will not follow the buckets downward and slow enough that the seeds will not be damaged by striking against the discharge chute. Capacities usually range up to 175 tons an hour. The horsepower required can be estimated as follows: Hp.=2 × tons per hour × the lift in feet, with the product divided by 1,000.

This type of elevator is not self-cleaning. Considerable time is required to clean it thoroughly when handling different lots of seed whose identity must be preserved. Good commercial vacuum cleaners are available, however, that make it easier to do a good cleaning job.

A self-cleaning vertical elevator for handling seed in bulk is available. It has two chains. A series of pivoted buckets is attached to the chains. The elevator has no lower boot and no discharge head at the upper end and is not enclosed in a housing. The seed is fed into the buckets by a feeder—a small hopper bin—between the two sets of sprocket wheels along the lower horizontal run. There is little or no spilling of the seeds, as the lip of one cup overlaps that of the adjoining cup. The seed is elevated and discharged into a distributor on the upper horizontal run. Little or no cleaning of the elevator is required between different lots of seeds. The danger of damaging the seeds is small.

Pneumatic conveyors, which carry materials within a pipe in a high-velocity stream of air, also are used for handling seeds in bulk. They are self-cleaning, simple, and inexpensive to maintain. The fan is the only major moving part. Seed can be conveyed up or down, around corners—anywhere the conveyor pipe can be laid. These conveyors eliminate much of the dust associated with seed handling. They have high power requirements. Seeds may be damaged unless the system is properly designed and operated correctly; therefore the indirect system of conveying should be used so the seeds will not pass through the fan.

Most seeds can be conveyed satisfactorily with air velocities up to 5 thousand feet per minute with little damage. From 35 to 50 cubic feet of air per pound of seed are needed to operate a low-pressure system. A rule of thumb is that seeds weighing 40 to 60 pounds a cubic foot can be conveyed at a rate of 4 tons an hour through a pipe 10 inches in diameter at an air velocity of 5 thousand f.p.m. Well-designed systems should convey one thousand pounds per hour per horsepower.

N. R. Brandenburg, of the Department of Agriculture, studied the possible application of fluidized conveying to handling seeds. It differs from conventional pneumatic conveying in that seeds move and act like a liquid as they move through a pipe. Velocity and power requirements are usually much less and the size of conveying pipe is much smaller for fluidized conveying. Air pressures are much higher. This method was in the development stage in 1961. It seems to have promise, particularly for seeds that are easily damaged.

Belt conveyors are used for moving seeds in bag or in bulk in a horizontal or inclined direction. Flat-belt conveyors are used for bagged or packaged seeds, and troughed-belt conveyors for bulk seed. They work smoothly and noiselessly. They can be run in either direction. They are well adapted to portable operation. They operate more efficiently at high speeds than any other continuous conveyor and there is little damage to the seeds. They are especially suitable for handling bags or packages.

Belt conveyors are limited to a maximum incline of about 17° for handling seeds in bulk. The recommended maximum speed is about 300 feet per minute for a belt 10 inches wide for conveying small seeds in bulk and up to 400 f.p.m. for such seeds as wheat, corn, and soybeans. About 10 f.p.m. can be added for each additional inch of belt width. Flat conveyors carrying bagged or packaged seeds generally operate best at about 100 f.p.m.

A RULE OF THUMB that can be used for estimating the horsepower required for any belt conveyor is to take 2 percent of the number of tons of seed carried per hour for each 100 feet of horizontal belt. For example: 100 tons per hour to be carried 150 feet $=0.02\times100\times1.5=3$ horsepower. For inclined conveyors, an additional 1 percent should be added for each additional 10 feet of rise in incline.

Portable belt conveyors, with platform elevators, are used in warehouses for piling bagged seeds, removing bags from the piles, and moving bagged seed into and out of the warehouse. They can move few or many bags at a time.

The industrial fork truck is used with pallets to handle bagged or packaged seed in warehouses that have suitable floors and column arrangements. This method is adapted to picking up and stacking unit loads—groups of bags or packages—rather than single bags and transporting the loads 500 feet or more.

Fork trucks with a capacity of 3 thousand to 4 thousand pounds are suitable for handling bagged seeds in many warehouses. They usually have a turning radius of 72 to 78 inches. They can be powered by electric, gasoline, or bottled-gas motors. They can travel 7 to 11 miles an hour.

Smooth, level floors and runways speed the movement of fork trucks. A 1-percent grade requires an additional 20 pounds of tractive effort per ton handled. Hard asphalt, good, smooth concrete, and planking make acceptable floors. Rough, uneven, and soft floors require additional power for moving the trucks. The spacing of columns and posts also affects their movement. Columns usually are 16 to 20 feet on centers in conventional wood-framed warehouses. The spacing in more modern warehouses may be greater. Aisles at least 10 feet wide are needed for easy manipulation of the trucks in handling loads into and out of the stacks. Main aisles should be about 20 feet wide.

Pallets form a natural base for transporting unit loads by fork truck. The 4- x 4-foot double-faced wood pallet is used widely because of its relatively low cost, fairly light weight, and durability. Metal skids of various types and sizes are also available, but generally at a higher cost. If the pallets accompany the rail and truck shipments, the charges for the return shipment of empty pallets often are sizable.

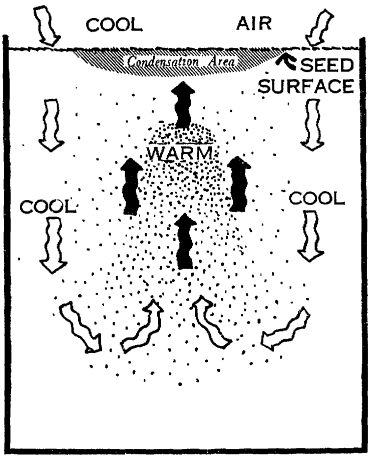
A pusher-bar installed on the front end of a fork truck can be used to push the load off a pallet onto the floor of the rail car or road truck, and the pallet need not be shipped.

Expendable one-trip paper pallets are used in some industries to save the cost of the return freight.

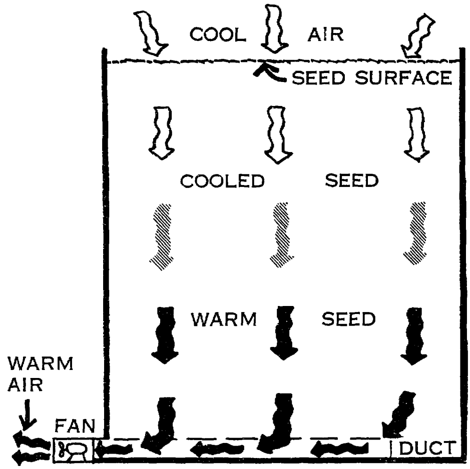
PORTABLE BINS, called tote bins or pallet boxes, were used in connection with fork trucks in some warehouses in 1959 to handle and store bulk seeds. These bins vary in size and design, but are large enough to hold about 50 bushels of small grains. Tote bins can be loaded by the producer, transported to the warehouse by truck, and handled into and in the warehouse by fork trucks. They also are useful for keeping lots of seed segregated during processing and storage. Tote bins are relatively expensive to buy, store, and maintain, particularly in places where they cannot be stored outside.

Screw conveyors are used somewhat for the horizontal movement of seeds that are not easily broken or damaged. These conveyors usually are as cheap as any other type, but power requirements are relatively high, and the

Natural Air Movement Causes Translocation and Condensation of Moisture in Stored Seed



Forced Air Movement (Aeration) Prevents Translocation and Condensation of Moisture in Stored Seed



length of single sections is limited. The main disadvantage is the tendency of the conveyor to crack or break the seeds, particularly when the trough does not fit the spiral closely and when the conveyor is operated at excessive speed. Capacities range from 250 bushels (300 cubic feet) an hour with a 6-inch-diameter screw operated at a recommended 180 revolutions per minute to about 6 thousand bushels (7,500 cubic feet), with an 18-inch screw at 120 r.p.m.

Seeds should be stored dry and kept dry.

The length of time that seeds can be stored without loss of viability depends largely on their storage environment. The main factors are the moisture content of the seeds while in storage and the temperature within the storage.

The simplest and oldest method of storage is to store dry seeds in bags or in bulk near air temperature. Many species can be stored in this way for a year or longer in well-managed conventional storages. Conditioned storage (40° to 50° F.) is necessary for longer periods, for certain regions, and for certain species of seed.

Special conditions may exist in stored seeds that can affect their storability. For example: Most seeds are good insulators. Wheat is 6 to 10 times as good as concrete. Even minor sources of heat at the center of a seed mass may cause a serious rise in its temperature so that hot spots develop. Temperature differentials can cause a movement of water vapor from the warmer to the cooler parts of the mass. Usually this happens in the upper layers of seeds, where warm air rising from within the mass hits the cool upper surface.

D. G. Carter and M. D. Farrar, of the University of Illinois, found moisture concentrations of 16 to 19 percent in the upper layers of soybeans that had an initial uniform moisture content of 12 percent before they were stored in bulk. This occurred after a few weeks in storage and as the outside air temperatures fell. Similar instances have been reported for other kinds of seeds. A surface layer of damp, moldy, and sprouting seeds may form as a result of this moisture translocation and accumulation.

Another common example of moisture translocation is the sweating of warm seeds in bags, particularly at the bottom of a pile stored on concrete floors. Sweating can be prevented by placing the bags on pallets or other material to keep them off the floor.

Bulk-stored seed often is turned—moved from one bin to another—to break up any undesirable hot spots and to equalize the temperature of the seed to prevent translocation of moisture. Better results can be obtained by aerating the stored seed—moving the air through it—rather than by moving the seed through the air. A motor-driven fan, with a suitable duct system, supplies the small amount of air needed for aeration (only one-thirtieth to one-fifth cubic feet of air per minute per bushel). Automatic controls permit the fan to operate only when air humidity and temperatures are within a selected range.

Seeds absorb or give up moisture until they are in equilibrium with the surrounding air. Eben H. Toole, of the Department of Agriculture, found in a series of studies that, at a relative humidity of 65 percent (80°), turnip seeds reached an equilibrium moisture content of 8 percent and kidney beans reached 12 percent. Most seeds will reach equilibrium within this range under similar atmospheric conditions.

Temperature has little effect on the moisture content of seeds at a given relative humidity, but it does have a decided effect on the rate of deterioration.

Dr. Toole offered the following recommendations concerning desirable humidity and temperature conditions for vegetable seeds: For seeds stored at 80°, the relative humidity should be no higher than 45 percent and no higher than 60 percent at 70°. Short-lived seeds, such as onion and shelled peanut, should be stored at a lower humidity under similar temperature conditions. For seeds in cold storage at 40° to 50°, the air relative humidity should be no higher than 70 percent and preferably no higher than 50 percent. The recommendations also apply to most field seeds.

Conditioned storage rooms usually are designed to provide storage temperatures between 40° and 50°. Relative humidity is controlled in some.

Unit systems—the factory-assembled equipment—are available in sizes from one-third ton to 20 tons. Often they are placed directly in the conditioned space. Built-up central systems, field assembled, can be designed in shape, size, and capacity for any application.

The size, in tons, of the cooling system needed can be estimated by dividing by 12 thousand the heat gain of the storage—heat gained from the stored seeds and through the walls, roof, and windows—expressed in British thermal units per hour.

It is seldom practical to operate a conditioned storage without some insulation in the walls and roof.

A rule of thumb for any storage held at 40° to 50° is to insulate with at least 3 to 4 inches of sheet or block insulation having a conductivity equal to that of corkboard. Unusual conditions of climate or use should modify normal recommendations. The manufacturer's recommendations should be followed.

Attempts have been made to use nuclear magnetic resonance to measure the moisture content of grain. If successful, this could provide a wide-range method that would be useful for the rapid measurement of the moisture content of seeds, the continuous monitoring of moisture during seed processing, and the determination of moisture content without destroying the seed.

If the temperature within a storage cannot be controlled, the operator can do little but work with the atmospheric conditions within and around the storage. Then he limits the moisture content of the seed he stores by receiving dry seed or by drying it after receiving. He also takes advantage of any good weather for ventilating warehouses, for circulating air around the stored bags to minimize extremes of high humidity and temperatures, and for aerating bulk stored seed to prevent hot spots and translocation of moisture.

Most field, grass, and vegetable seeds will store for a season with no serious loss in viability if their moisture content is not more than 12 to 12.5 percent.

For example, we found in studies in Illinois that soybeans stored in bulk at 12 to 12.5 percent moisture maintained their viability for some 175 days; those at 8 to 9 percent, for more than 650 days; but those at 15 percent, for less than 50 days.

Sealed storage, or storage under inert gases, presents some attractive advantages for preventing growth of mold and insect activity in stored seeds.

Some dangers are involved, however. Anaerobic—absence of oxygen—respiration of the seed can occur. It soon produces dead seed. Damp seeds may be killed as quickly under anaerobic conditions as in free air. Seeds to be stored in sealed containers or bins therefore should be at least 1 percent drier than seed stored under ordinary atmospheric conditions.

Bagged seeds are stored in both single- and multiple-story warehouses. The main requirements are weathertight roofs and walls; strong, smooth floors and properly spaced columns that permit the efficient use of fork trucks and other machines; and ceiling and truss heights that permit bags to be stacked 16 feet and higher.

Bulk seeds are stored in bins or tanks separate from or within warehouses. The strength required for these storages varies with their size and the kinds of seeds to be stored. Wheat, soybeans, alfalfa, and clover, each weighing 48 pounds per cubic foot, are some of the heavier seeds that are stored in bulk.

Bin walls and floors must be strong enough to support both the lateral (horizontal) and vertical pressures exerted by the stored seed.

The design of structures for bulk seed or grain is complicated, but the following general conclusions can be offered: The pressure of the seed on bin walls and floors follows the law of semifluids rather than that of fluids. The lateral pressure of seeds on bin walls is but 0.3 to 0.6 of the vertical pressure and increases little after the seed depth is 2.5 to 3 times the width or diameter of the bin. The ratio of the lateral to the vertical pressure, which can be determined only by experiments, is not constant but varies with different seeds and bins.

Storages for bulk seeds normally should be designed by an engineer familiar with the structural requirements, or well-tested and recommended plans should be used.

Rodents are a problem in seed storages and warehouses. In one multistory bag storage in Maryland, each floor is isolated so no mice or rats can get onto a floor except in bags of incoming seed. The operator does not depend only on seeing the live rodents. He judges their presence by the signs they leave. An open space about a foot wide is left between the stacked bags and the wall, and this strip of floor is painted white. Rodent tracks and excreta show up easily on it. Traps, poison, or gas are used to get rid of the occasional rodents that do get in. The regular fumigations are depended upon for control in some warehouses and storages.

LEO E. HOLMAN *is an agricultural engineer in the Transportation and Facilities Research Division, Agricultural Marketing Service. He began supervising research on handling and storing seed and grain for the Agricultural Marketing Service in 1954. He has written widely on the design and use of aeration systems in maintaining the quality of stored grain. His degrees are from the North Dakota State University.*

JAMES R. SNITZLER *is an associate member of the W. B. Saunders & Co., Transportation Consultants, Washington, D.C. He was formerly an employee of the Department of Agriculture from 1952 through August 1960. Since 1956 he served as Assistant Chief, Transportation Research Branch, Agricultural Marketing Service. He has written many research publications on transportation economics.*